

Atlas Level 1 Trigger

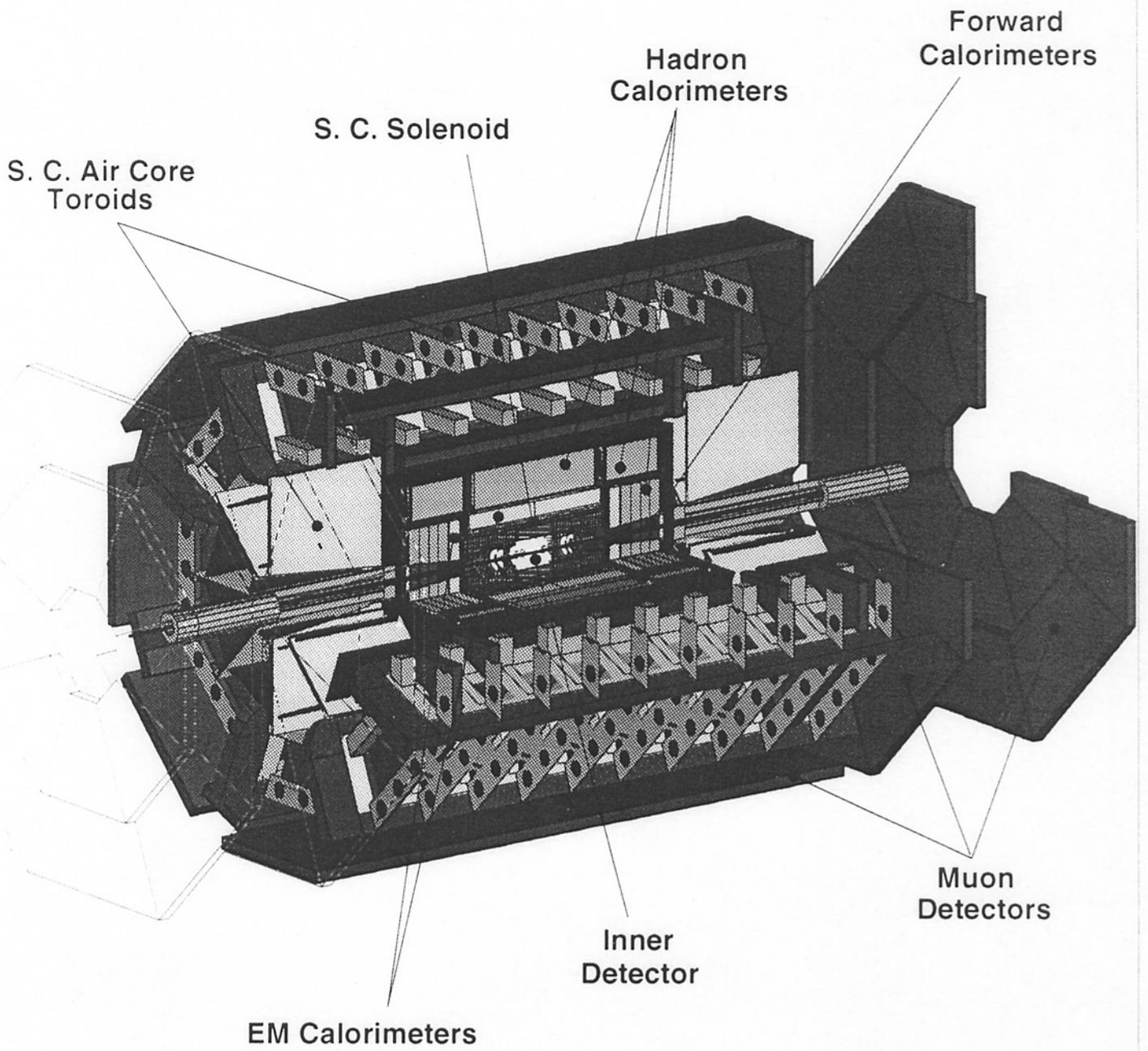
Are there lessons for RHIC?

Bill Cleland

University of Pittsburgh

Bunch Crossing Intervals

- ◆ LHC
 - 25 ns
- ◆ Upgraded RHIC
 - 35.5 ns
 - 11.9 ns
 - 8.8 ns
 - 5.0 ns



L1 Objects in ATLAS

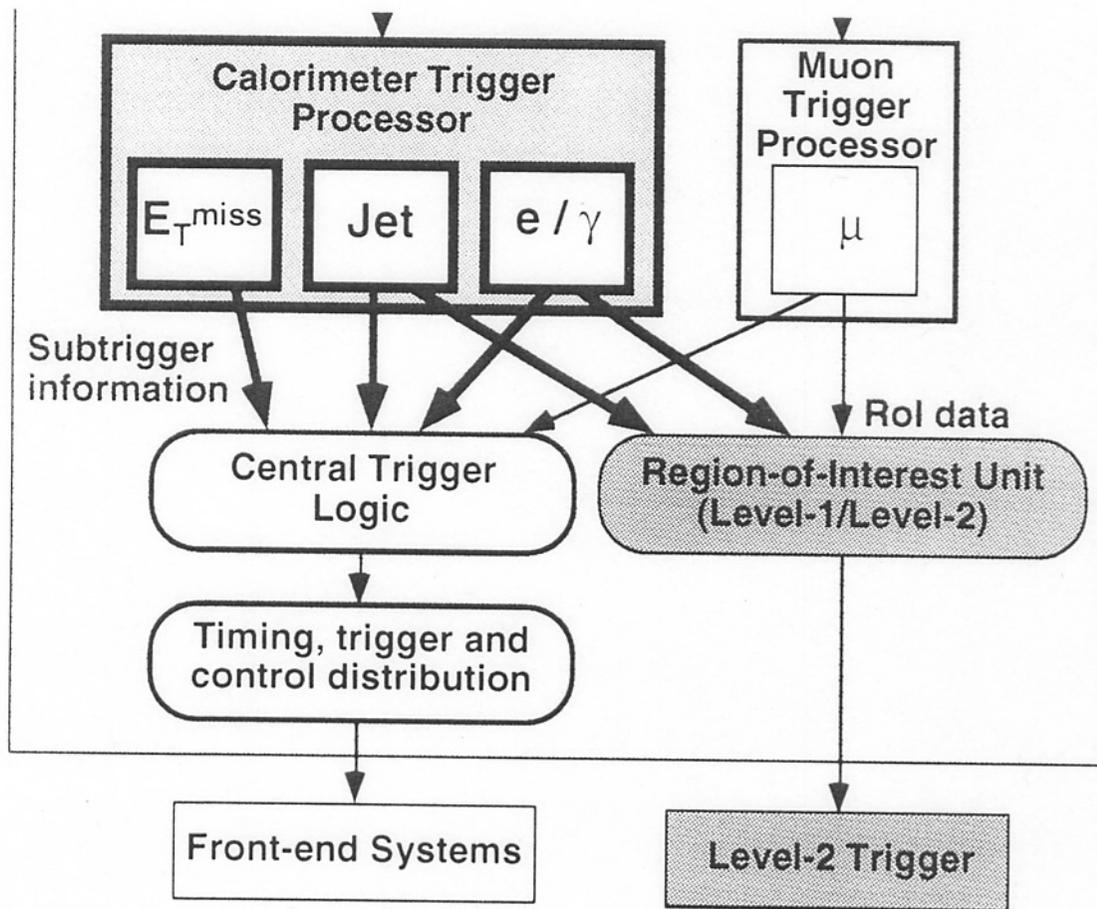
- ◆ Objects
 - Muons
 - EM clusters (isolated)
 - Tau ($\tau \Rightarrow$ hadron or hadrons, isolated)
 - Jet
 - Missing E_T
 - Total E_T
- ◆ L1 trigger = combinations of these objects

Properties of a (good) L1 Trigger

- ◆ Does not exclude interesting objects
- ◆ Creates biases which are calculable
- ◆ Has high selectivity
- ◆ Identifies bunch crossing of interest
- ◆ Has low latency ($\sim 2 \mu\text{s}$ in ATLAS)

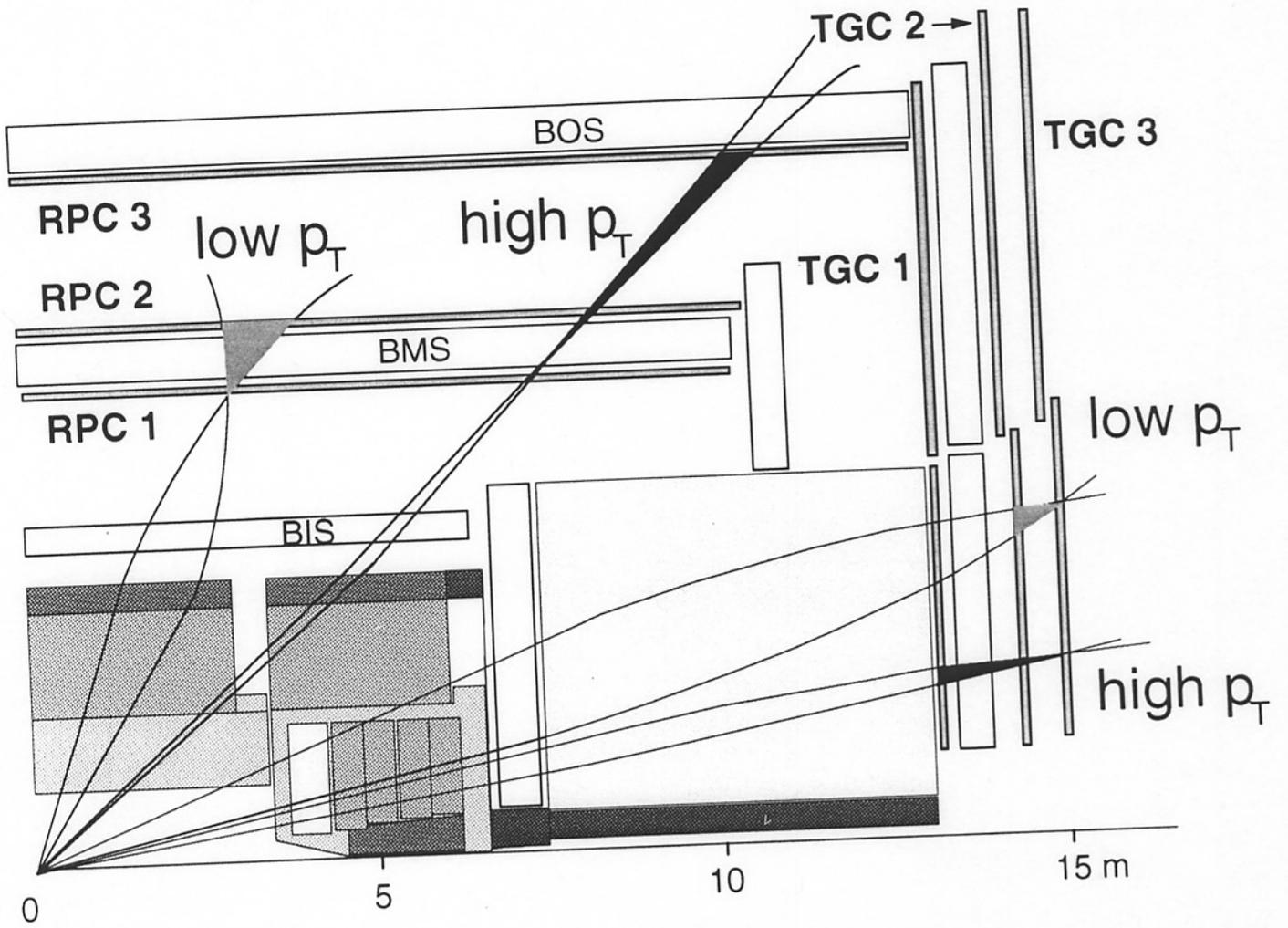
Detectors used for ATLAS L1 Trigger

- ◆ Tracking chambers (in muon system)
 - Resistive Plate Chambers (barrel)
 - Thin Gap Chambers (endcap)
- ◆ Calorimeters
 - Liquid Argon (barrel + endcap)
 - Scintillator tile (barrel+extended barrel)



Muon L1 Trigger

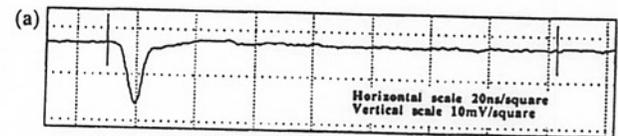
- ◆ Measures number of muons above thresholds ranging from 6-35 GeV/c
- ◆ Basic philosophy is to form coincidences starting from a "pivot" plane.
- ◆ Acceptable hits in other planes are defined by "cones" whose size is threshold dependent
- ◆ Majority logic is used to improve efficiency



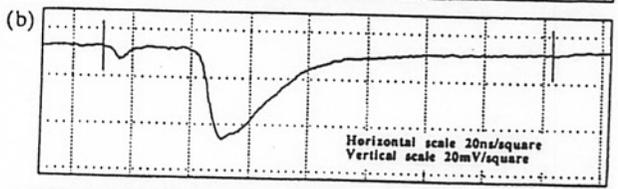
Resistive Plate Chambers

- ◆ Timing resolution of a few nanoseconds
- ◆ Orthogonal strips give 2D readout
- ◆ Uses low gas gain to improve rate capability
- ◆ Rate capability : 1 kHz/cm²

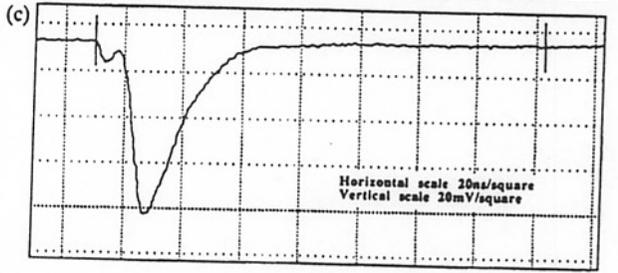
RPC signals



9.4 kV
avalanche mode

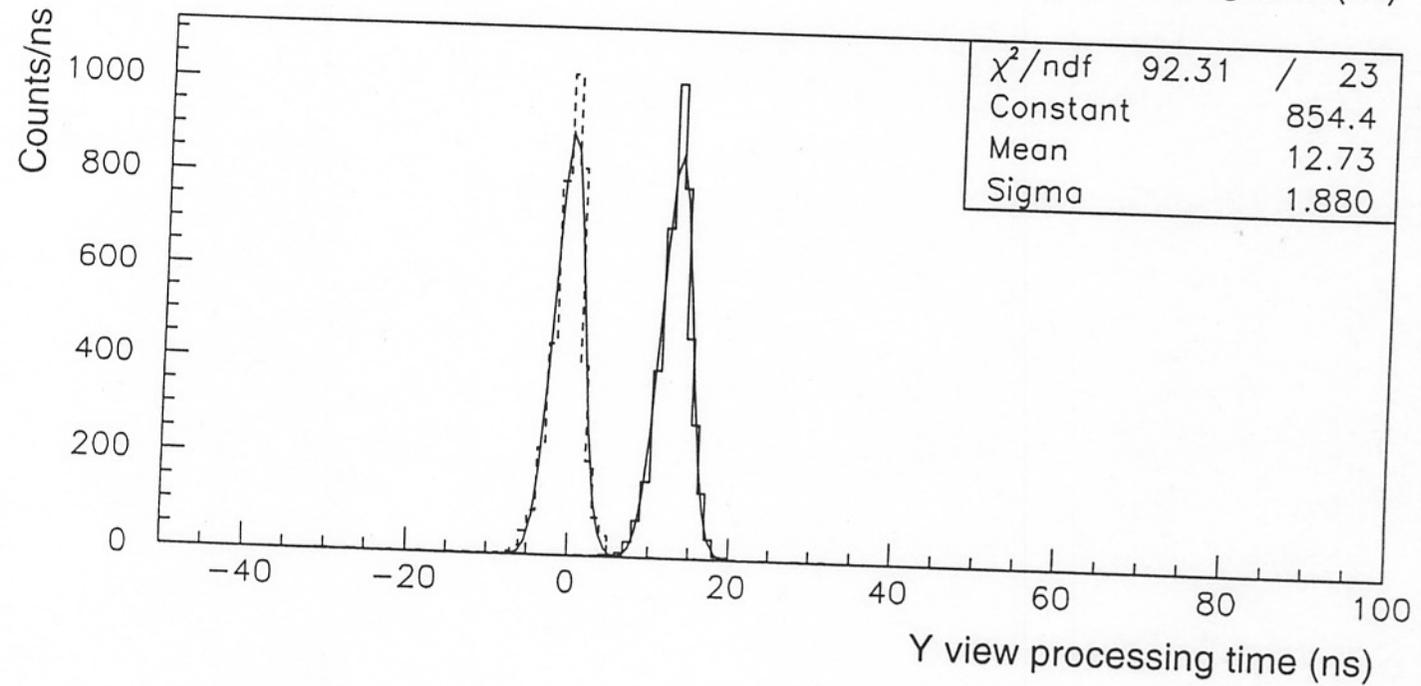
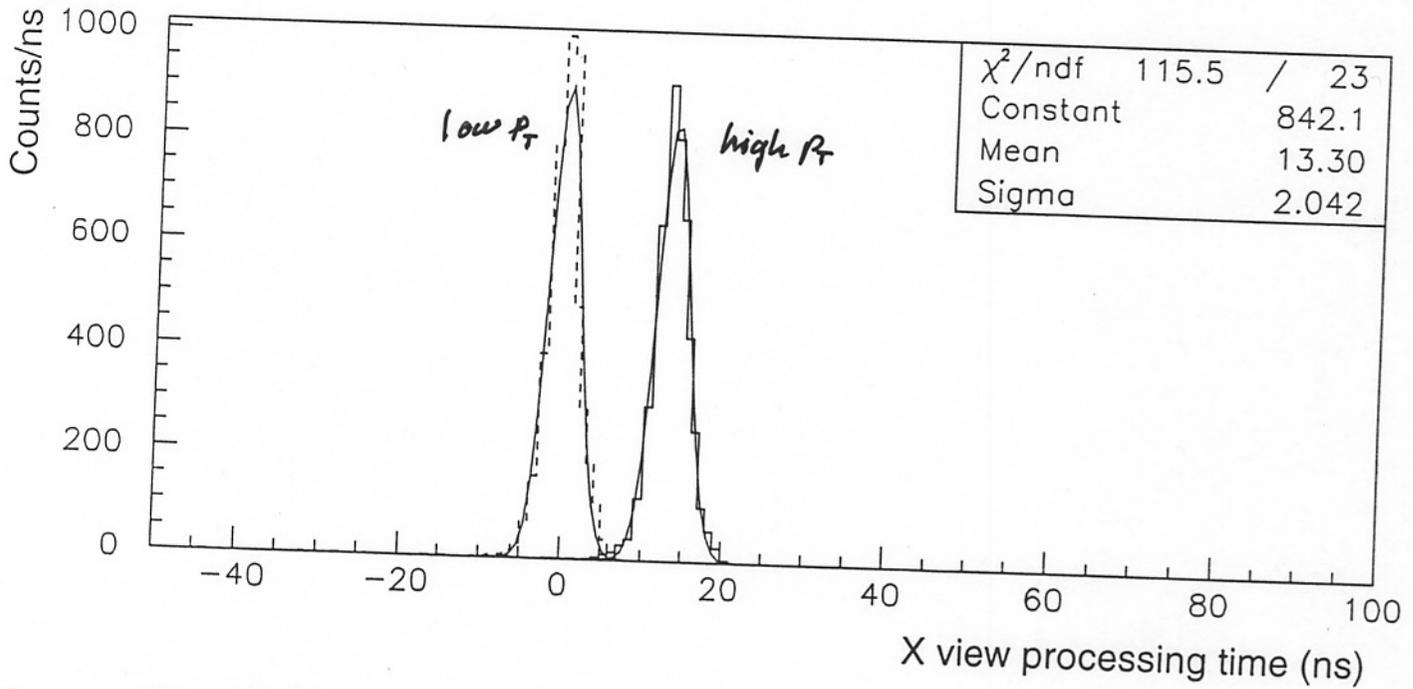


9.6 kV



10.2 kV
streamer mode

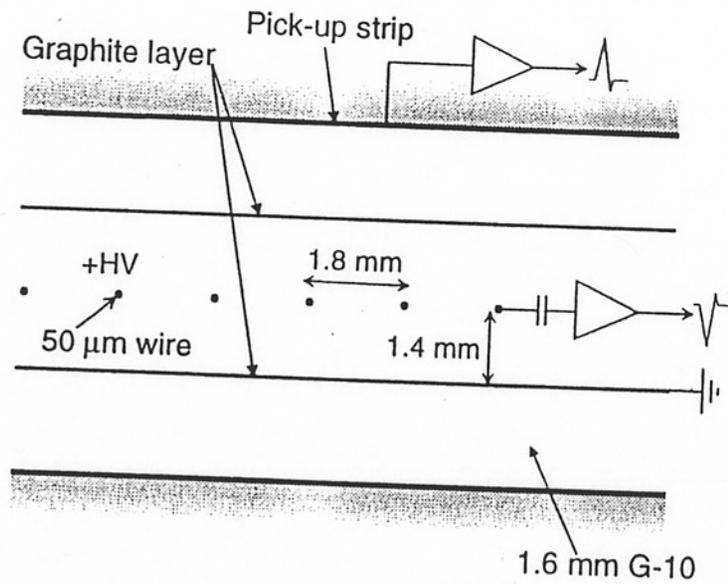
Processing time jitter for RPC Level 1 trigger signals



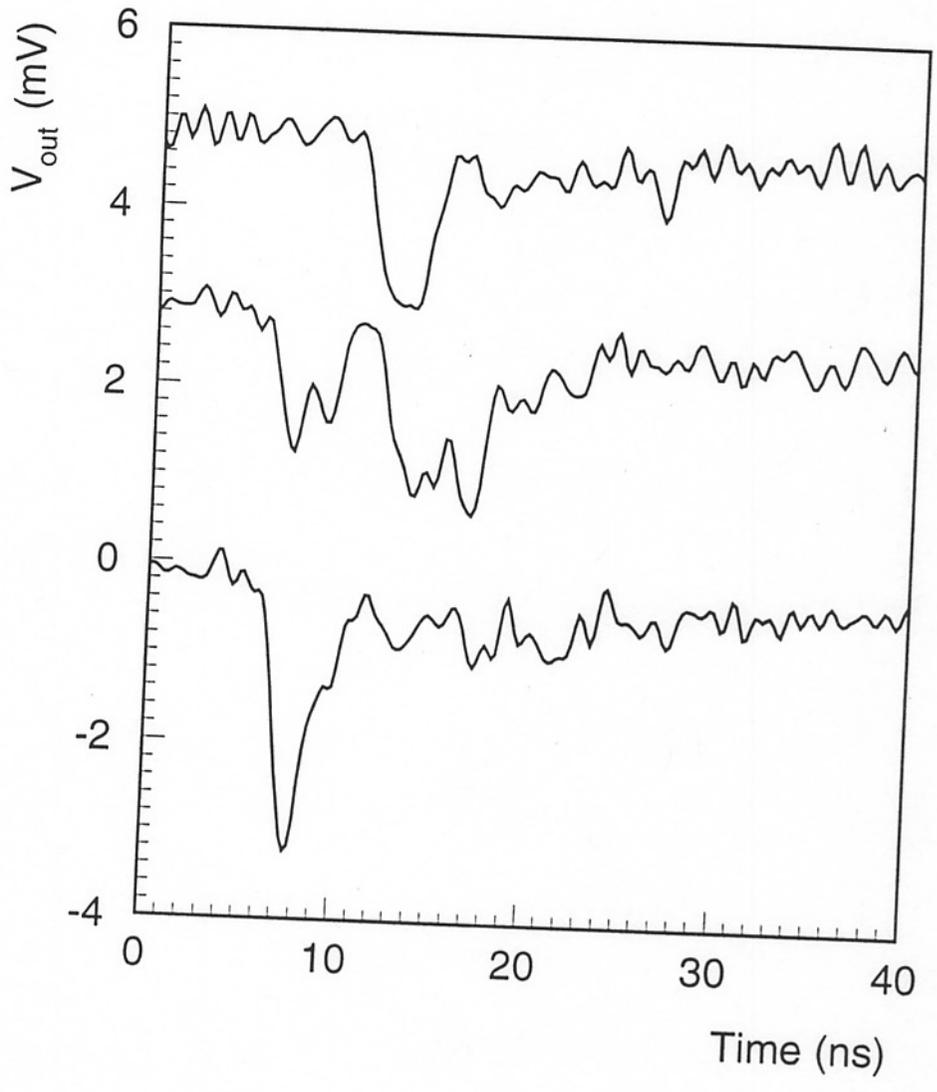
Thin Gap Chambers

- ◆ Similar to MWPC in construction
- ◆ Saturated-mode operation
- ◆ Time resolution of 5-10 ns
- ◆ Rate capability: 150 kHz/cm²
- ◆ Low sensitivity to magnetic fields
- ◆ Anode wires + cathode strips used for 2D readout

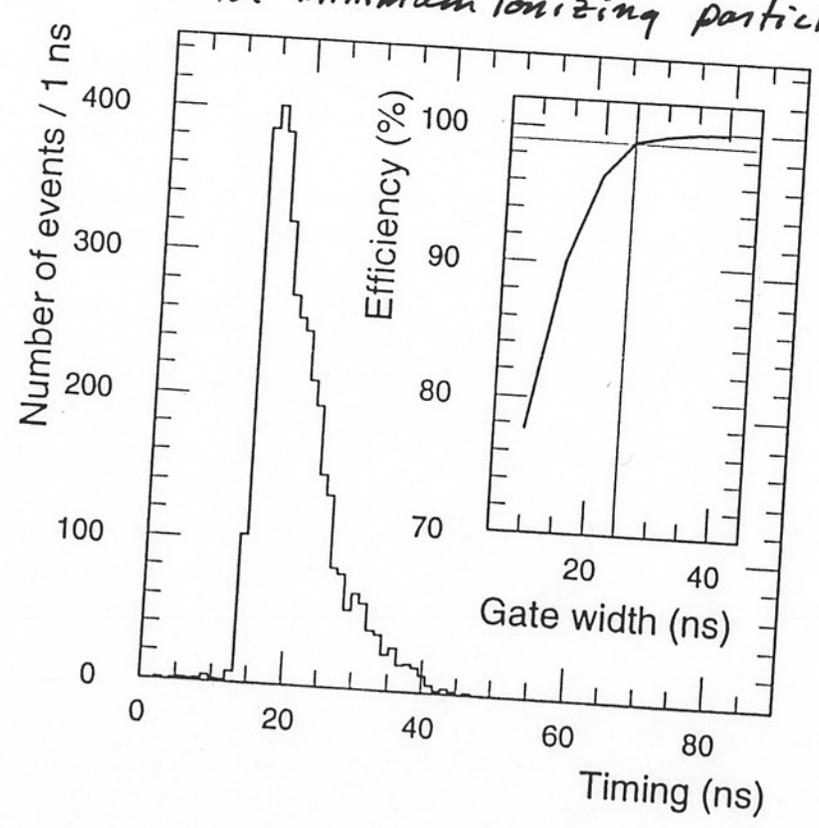
Thin Gap Chamber



TGC signals



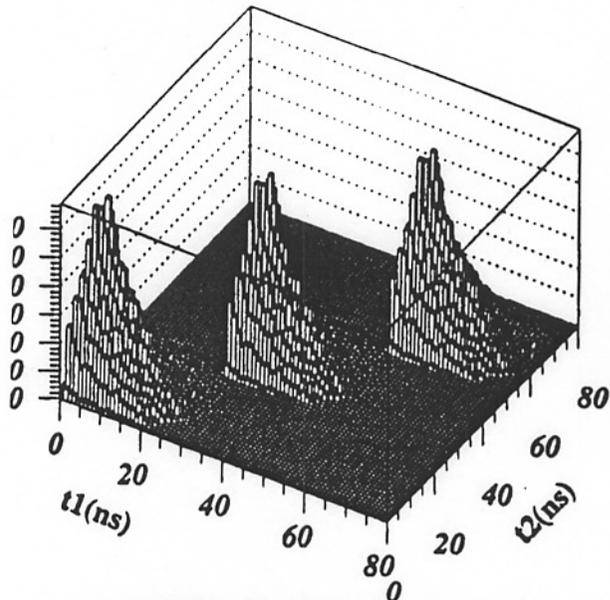
Thin Gap Chamber
Arrival time distribution
for minimum ionizing particle



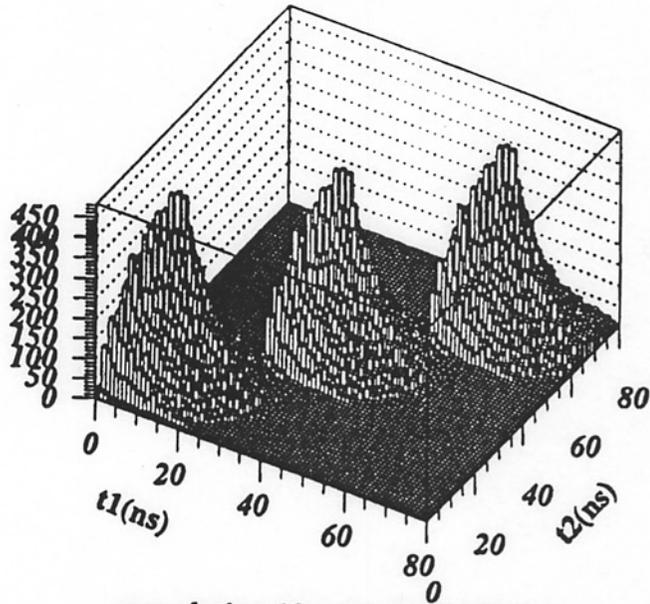
TGC: time correlation between 2 planes

wires

strips

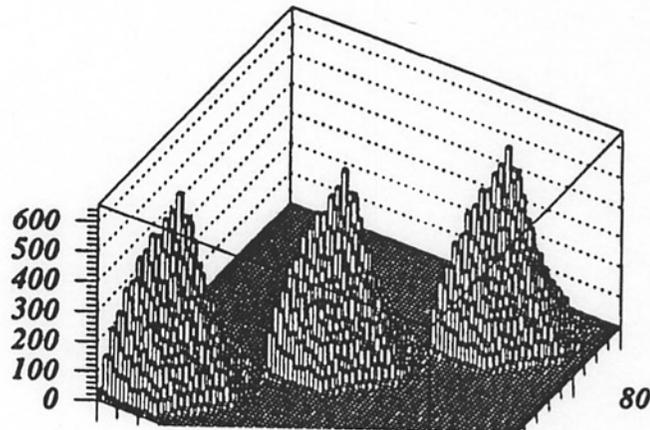
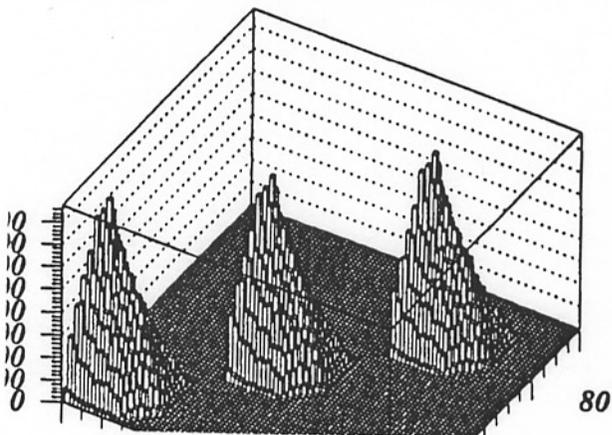


convolution 7ns incidence 10 degree



convolution 13ns incidence 10 degree

10°



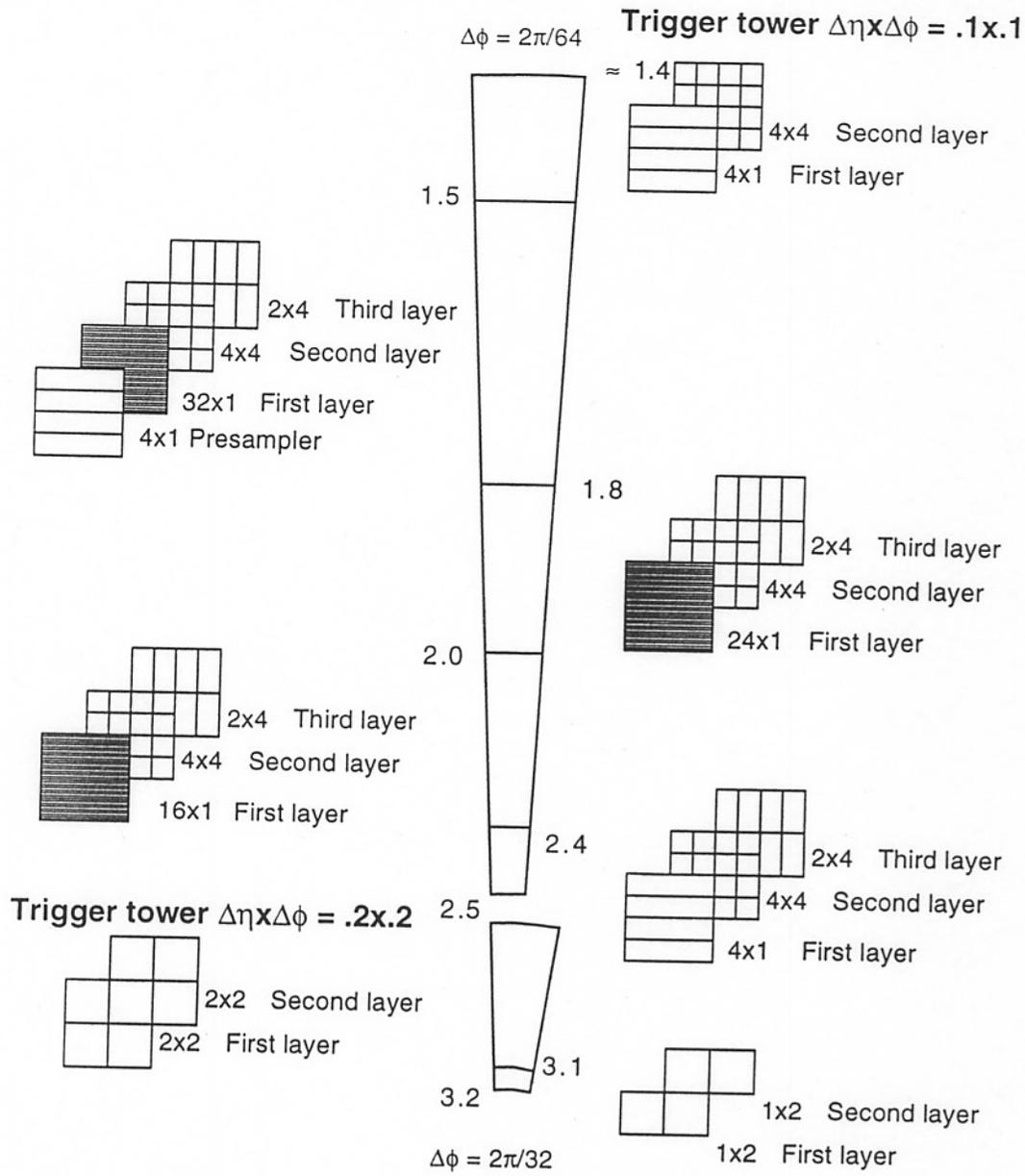
30°

Calorimeter Trigger Sums

- ◆ Trigger towers (Liquid argon)
 - 0.1×0.1 for $\eta < 2.5$
 - 0.2×0.2 for $2.5 < \eta < 3.2$
 - 0.4×1.6 for $\eta > 3.2$
- ◆ Analog sums are formed on the detectors, brought to L1 cavern on ~ 70 m copper cables
- ◆ Energy scale: $250 \text{ GeV } (E_T) = 2.5 \text{ V}$

Liquid Argon Calorimeter

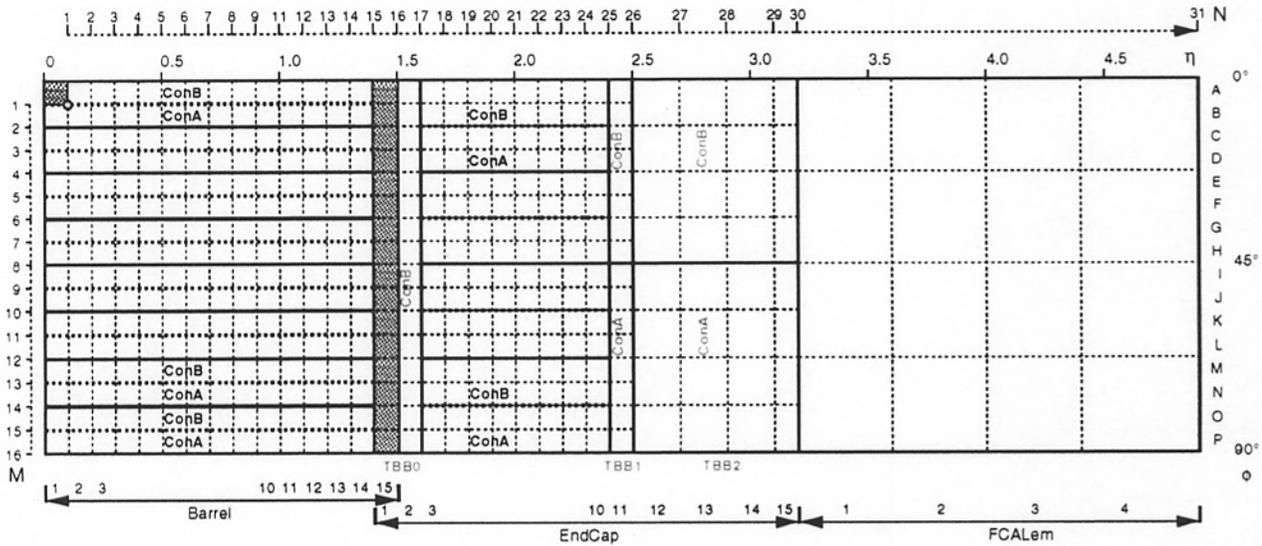
- ◆ Ionization current typically $2.5 \mu\text{a}/\text{GeV}$
- ◆ Drift time typically 400 ns (FCAL shorter)
- ◆ Bipolar shaping: CR-RC² with $\tau = 15 \text{ ns}$
- ◆ Peaking time (after cable) is about 50 ns
- ◆ Amplitude of peak is proportional to energy
- ◆ Trigger sums formed in 3-stage tree which makes conversion to transverse energy



ATLAS Level-1 em. Trigger Towers

2. ECAL: TowerBuilder Output

Aug99.ph



ECal: Barrel / Endcap OVLp

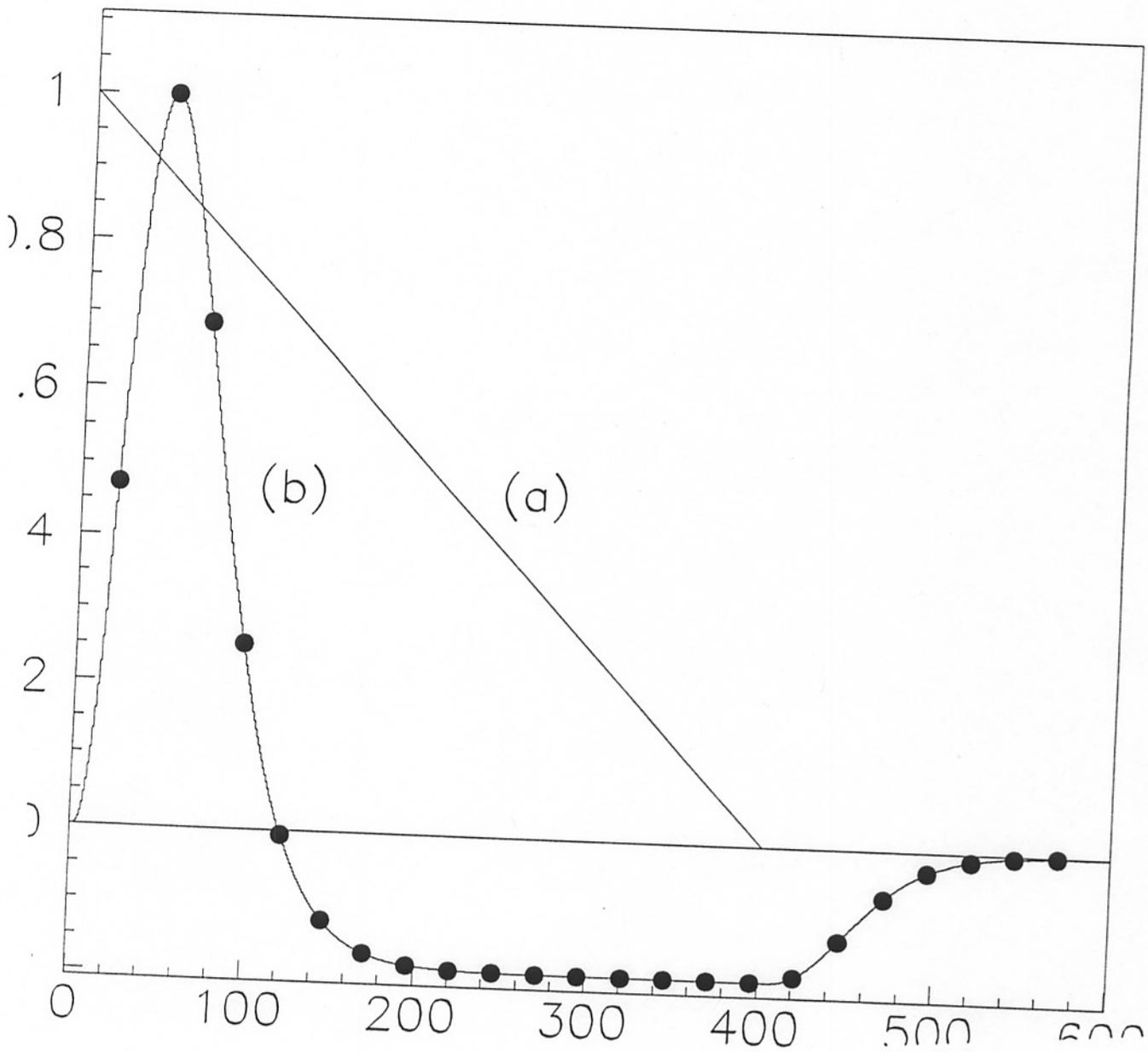
Trigger Cell with origin

M PHI-index of trigger cell

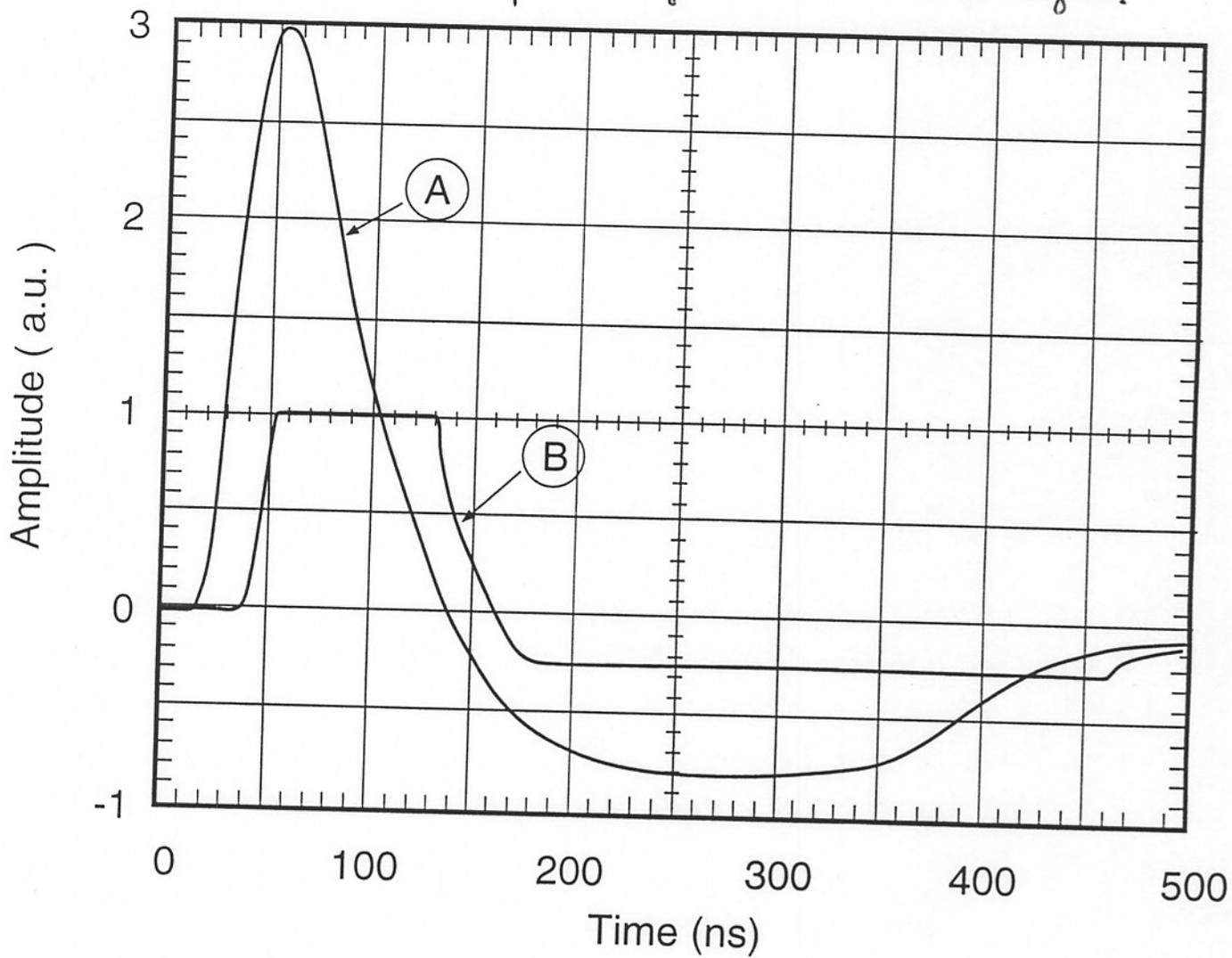
N ETA-index of trigger cell

ECal EndCap
("special" TBB0 and TBB1)

25 ms samples on liquid argon signal

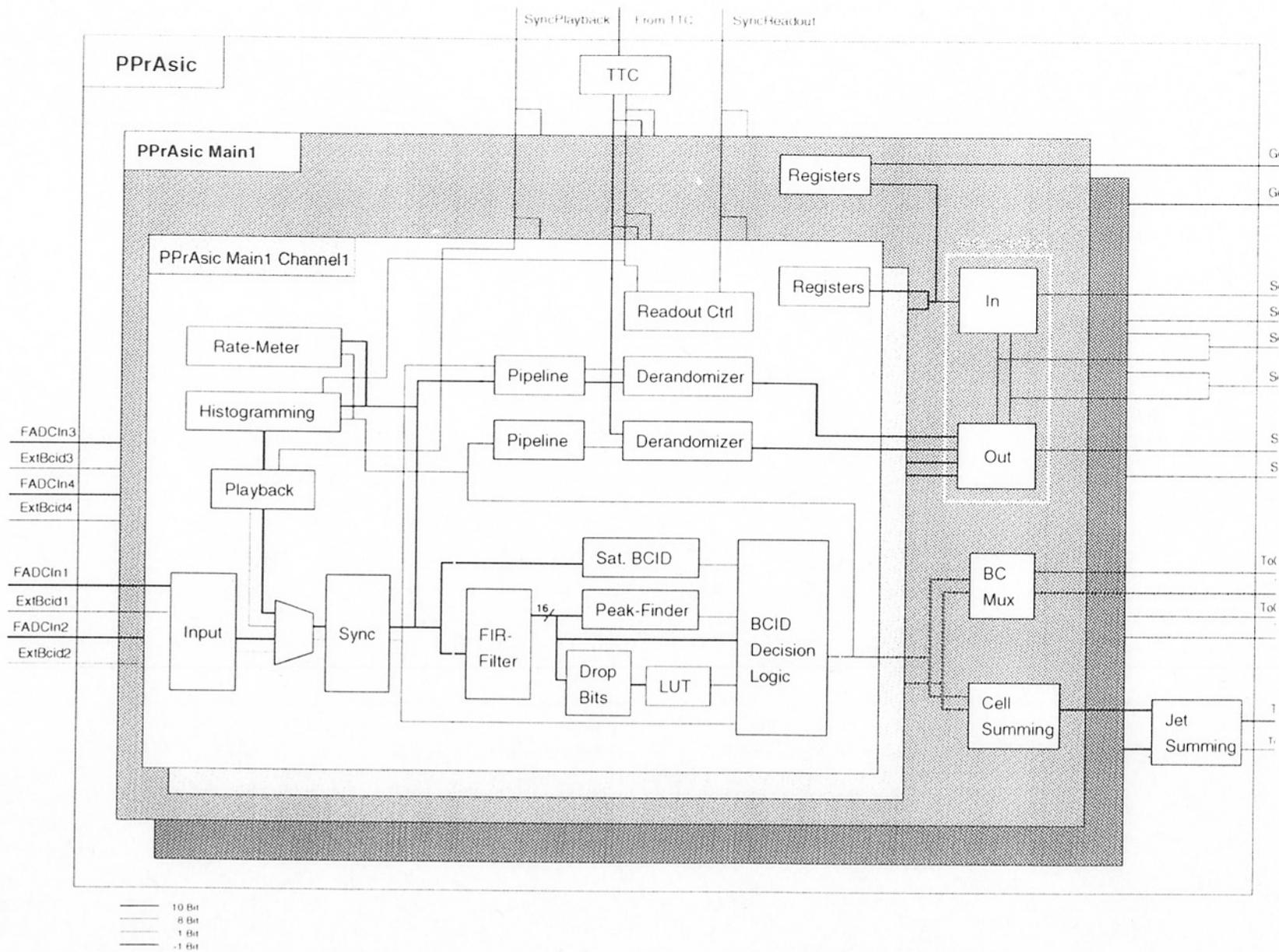


liquid argon - saturated signal



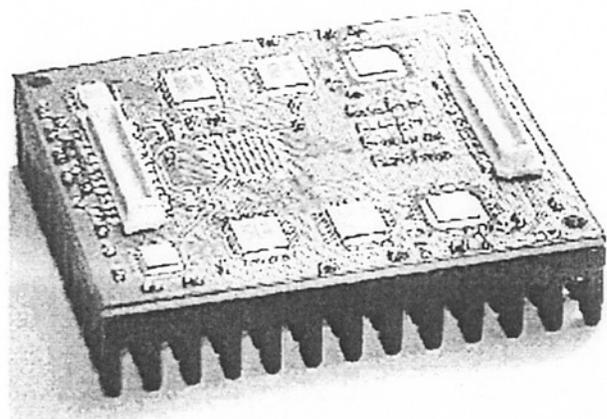
ASICs

- ◆ The high density of interconnections and the low latency requirements make ASICs a natural technology choice
- ◆ The use of custom ASICs along with commercial chips (ADCs) is used in the calorimeter L1 trigger in ATLAS
- ◆ The two types of chips are bonded to a common substrate in a Multi-Chip Module



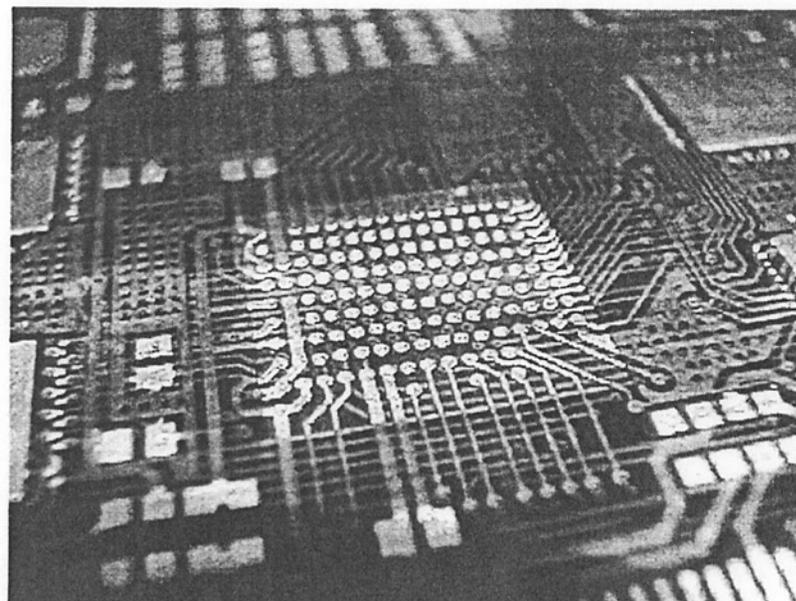
[Demonstrator]

Assembled:



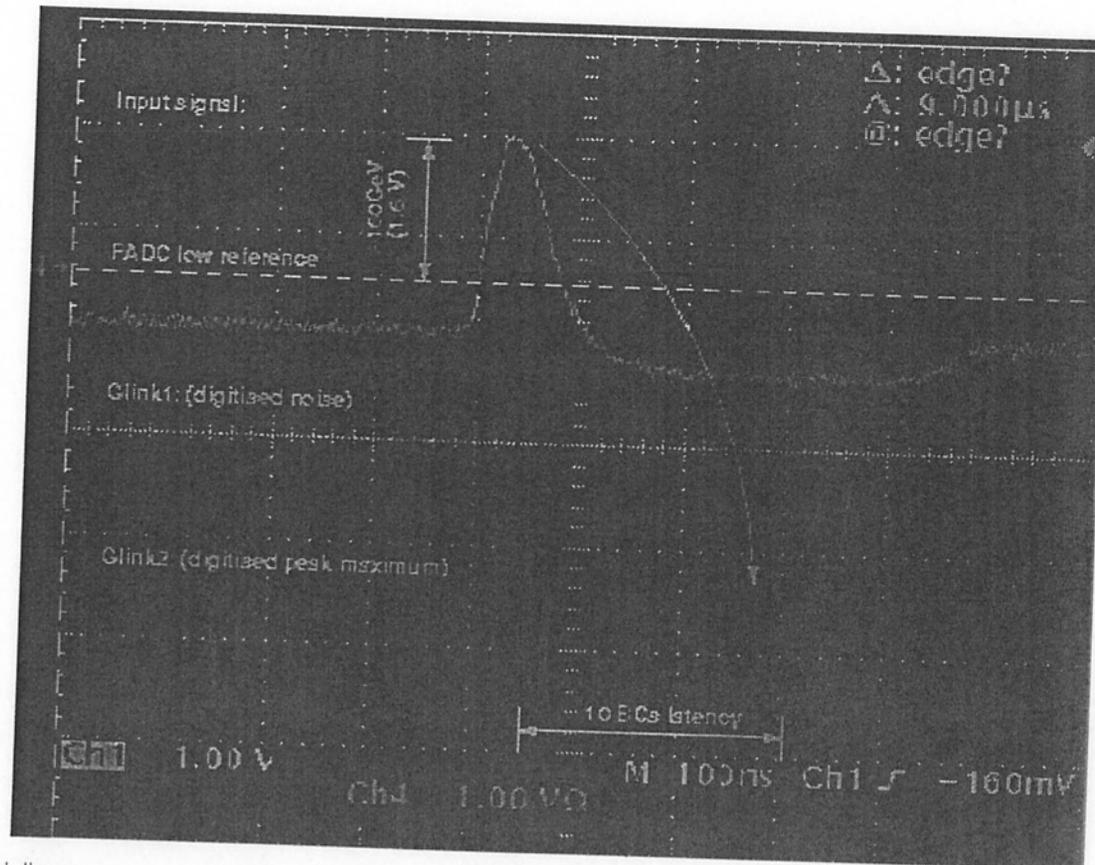
4 trigger towers are
fully processed on one MCM
size 4.3 x 3.7 cm

Substrate view:



Results / Performance (cont.)

- R&D finished
- Demonstrators showed, that functionality is reached WITHIN requirements.



Paul HANKE, KIP Heidelberg

Tile Calorimeter

- ◆ Plastic scintillator read with photomultipliers
- ◆ Shaping is dictated by sampling frequency of 40 MHz
- ◆ Unipolar pulse with 50 ns FWHM
- ◆ Trigger towers are $\Delta\phi=0.1$, $\Delta\eta$ is 0.1 below $\eta=0.8$ and 0.2 at higher eta (extended barrel)

Tile cal shaped signal

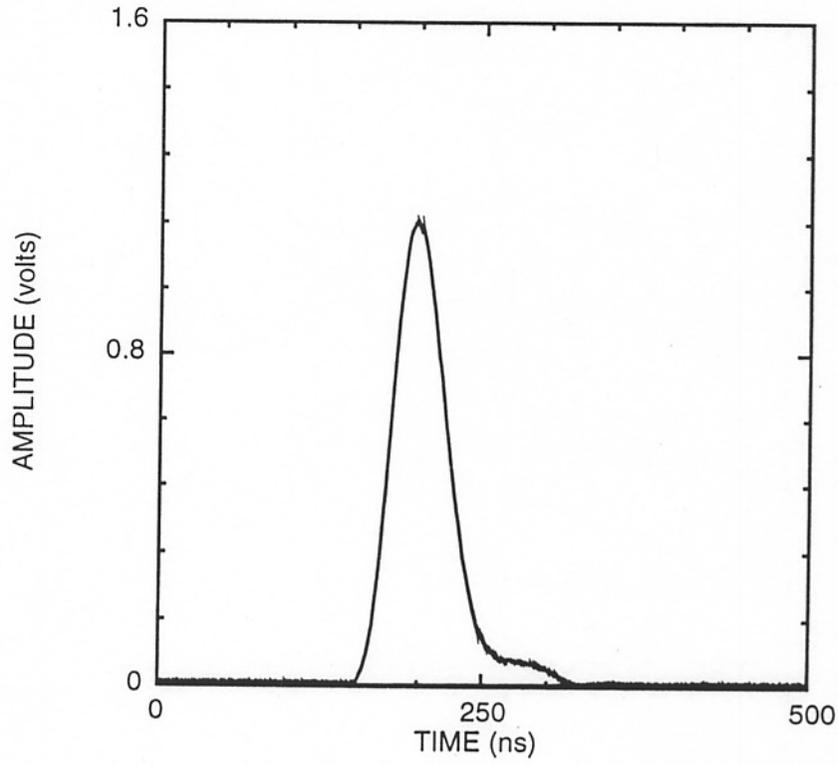


Figure 3: Typical form of shaped signal and its behaviour around the maximum (time is in ns).

Field Programmable Gate Arrays

- ◆ Initially much of the custom L1 trigger logic was planned around ASICS
- ◆ FPGAs are sufficiently fast that they offer a cheap and flexible alternative
- ◆ With FPGA-based modules, the L1 group has discovered that modules can be designed to serve multiple uses
- ◆ On-detector use of FPGAs is discouraged

Summary

- ◆ Bunch crossing identification is a critical function of the L1 trigger for detectors with inherent response time jitter.
- ◆ Requirements for detectors for L1 trigger is tied to choice of bunch crossing frequency.
- ◆ Multiple sampling and digital filtering are useful tools in this environment.